

1.

THE MANUFACTURE OF "ARSENIC", AND THE DISEASES MOST COMMON
AMONGST THE MEN ENGAGED IN IT.

By the term "Arsenic" I mean "Arsenious Acid" (Arsenious Anhydride) As_2O_3 - or as it is called in commerce "White Arsenic", and in shops "Arsenic".

In appearance it resembles Flour, but is heavier, having a sp:gr: of 3.7 - Microscopically it is seen as irregular glassy fragments, and Octahedral crystals.

When heated it softens (unless in a sealed glass tube, when it fuses). It is converted into vapour at 380 F, depositing Octahedral crystals on a cool surface.

Arsenic has a slightly sweet taste, but is almost tasteless. It is sparingly soluble in cold water.

The smallest fatal dose hithertoo recorded is "two grains", showing its poisonous character, and the necessity of exercising great care when dealing with large quantities. Seeing what a powerful poison it is, one is surprised at the large quantity which is produced annually, viz. over 5000 tons.

This amount is obtained from Cornwall, Devon and South Walse. In 1899 there were registered under the "Alkali &c Works Regulation Act", 30 Works, of which 26 are situated in Cornwall, 3 in Devon, and 1 in South Wales.

The greater number are situated on the banks of the River Tamar, which divides Cornwall from Devon, and are spoken of as the "Tamar Valley Works", from which by far the greater part of the Arsenic comes.



All the Arsenic Works in Devon are situated on the East bank of the River Tamar, and include two very large works, viz: Devon Great Consols, the largest of all the Arsenic works, and Gawton. Devon Great Consols in 1898 produced 1723 tons of pure Arsenic. It was formerly worked for Tin, but for the last 56 years has been worked for Arsenic as well. The mine shaft in connection with these works has been sunk to a depth of 300 fathoms in quest of Tin, but the productive part for Arsenic is 140 Fathoms. In this mine 450 men are employed of which 365 are miners who work underground, and bring to the surface the Ore which contains the Arsenic, and 85 are men who are employed in the manufacture of arsenic and work above ground. Gawton Mine is not so old as Devon Great Consols, having been worked for Arsenic for 25 years, and its mine shaft has been sunk to a depth of 130 fathoms. The quantity of pure Arsenic manufactured here in 1898 was 1041 tons.

Most of the Cornish works are situated on the West Bank of the Tamar, and are near the two works mentioned above. They include Greenhill Works, which in 1898 produced 400 tons of Arsenic; and Coombe a smaller Works still. In West Cornwall there ^{are} 2 Works near Truro, in Devoran Parish, called the Carnon Arsenic Works & the Cornwall Company's Works Ltd, which are close together; and still further West, near the Land's End, the Lelant Mine.

Some of the Arsenic Works are situated close to the

mine shaft; Devon Great Consols and Gawton being examples. Others are at some distance from the place where the Ore is raised, such as Greenhill, Carnon Arsenic Works and the Cornwall Arsenic Company's Works.

Miners bring up the Ore to the surface, and it is when raised, and on the Arsenic Works, that it concerns us.

The Ore from which the Arsenic is obtained is called Arsenic Mundic. It is very heavy, light brown in colour, with a metallic lustre, and very hard. It contains from two to forty-eight per cent of Arsenic, and also some Sulphur, of which the less the better, it being a waste product. There is also present in this mundic some Copper, which varies in amount, some specimens showing the brassy lustre well marked, others very little; some Tin; Silver, which may be 2 to 3 oz per ton, and a little Gold. The percentage of Arsenic in the ores treated varies much. The Tin ores are at one extreme, and the Arsenic obtained is but a bye-product, while the Arsenic in pyrites may vary from 20 to 30 per cent. Ores are raised which may contain any or all of the following: Arsenical Pyrites, Iron Pyrites, Copper Pyrites, Tinstone, Wolfram, Blende, and Galena.

The Process by which the Arsenic is extracted consists in roasting the Ore in a furnace, by which the Arsenic and Sulphur are oxidised and driven off as Arsenious Acid and Sulphurous Anhydride. The

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Arsenious Acid is intercepted in Chambers constructed in the course of a Flue, through ^{which} all the products of combustion pass, between the furnace and the Chimney. The Arsenic is however discoloured by the dust and smoke of the fire, and must consequently ^{be} resublimed in a Refining Furnace, where only Coke or Anthracite is burnt, to be again collected in a series of settling chambers in the Flues.

I will now describe fully the different steps taken in the manufacture of Arsenic, from the Arsenic Mundic on one hand to the pure Arsenic packed in Barrels, ready for market on the other, and in doing so I will describe what I saw at the Gawton Mine, where the Plant and machinery are of the modern type.

After the Ore, (the Arsenic Mundic,) is brought to the surface by the miners, the Arsenic workers take charge of it. The first thing they do is to put aside any pieces which seem rich in Copper, these are treated separately, and after roasting sold as Copper Ore, which contains about $2\frac{1}{2}\%$ of Copper and 1 % of Arsenic, still in it, not sublimed. The mundic being in more or less large lumps, is broken into pieces half an inch in size by being put through a steam Stone breaker, which can break 200 tons a day. It is then reduced to the size of fine gravel by the crushers, when it is ready for the roasting process.

Roasting the Gravel is termed Calcining, and is done in Calcining Furnaces of which there are three kinds,

1. Brunton's Calciner
2. Revolving Tube Calciner.
3. Reverberatory Calciner.

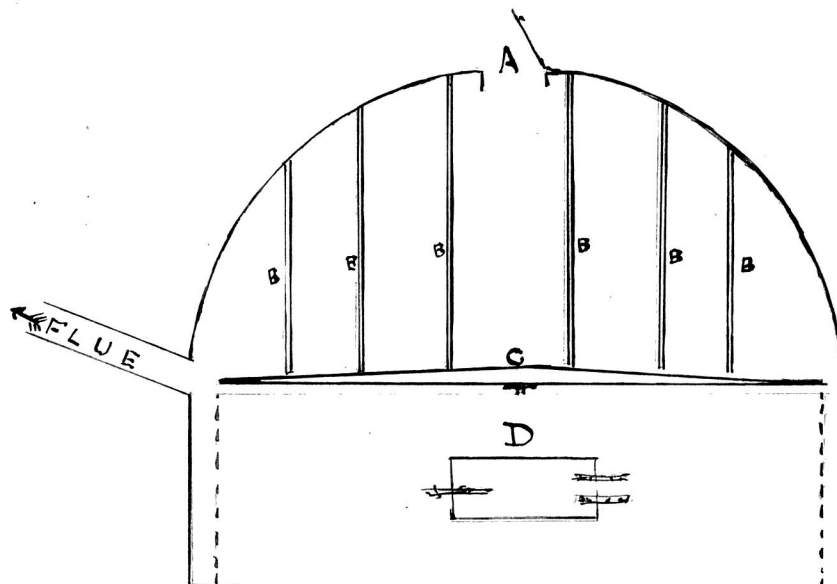
Brunton's Calciner.

This consists of a dome of Fire-brick, at the top of which is an opening through ^{which} the crushed ore falls on to the floor of the Calciner which is formed of a bed of bricks, the centre of which is higher than the circumference, and which revolves by means of a Water-wheel at the rate of once in a quarter of an hour. By means of six perpendicular iron bars, which are suspended from the inner surface of the dome, and nearly reach the bed, the ore is made to travel from the centre where it enters to the periphery, and by the time it gets there all fumes cease to rise, showing that all the Arsenic and Sulphur have been volatilised, and have gone up a flue which leads out of the Calciner. After the ore is roasted it falls into a Chamber below. Beneath the bed of the Calciner is the Furnace. At the Gawton Works there are six of these Calciners, and each can burn six tons of ore a day.

The Revolving Tube.

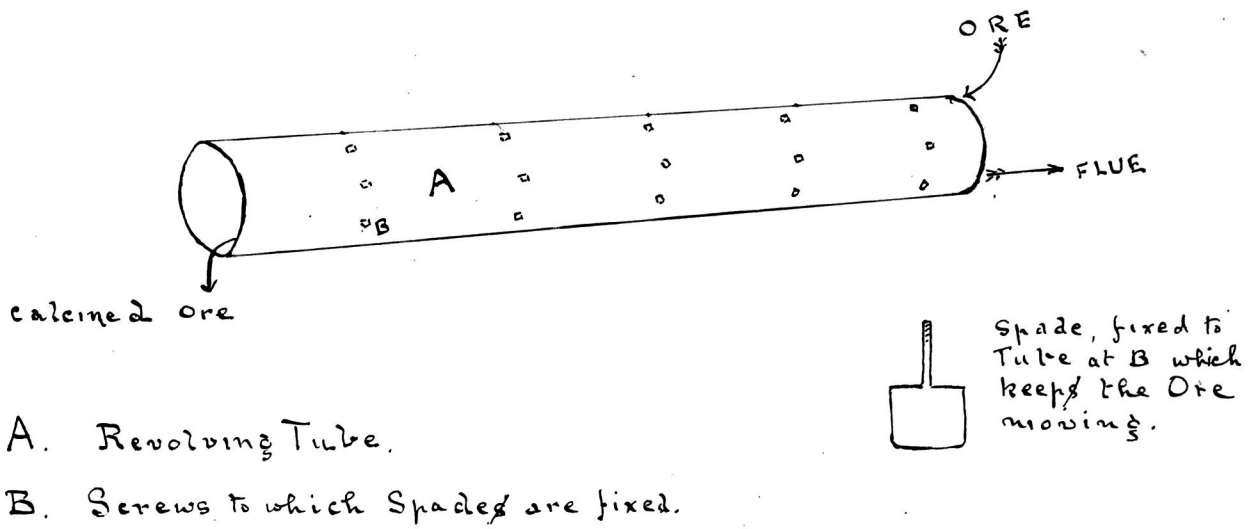
The Revolving Tube or "Oxland" Calciner is a wrought iron cylinder, mounted in an inclined position, and made to revolve slowly by machinery, about once in eight or ten minutes. The fire place is at the lower end. The ore is introduced from the top, and as the tube revolves it is lifted by means of spade-like

BRUNTON'S CALCINER.



- A. Opening through which the Ore falls.
- B. Iron Bars.
- C. Bed of Calciner.
- D. Furnace.

REVOLVING TUBE CALCINER.



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pieces which project from the inner surface of the tube so that the falling particles become exposed to the oxidising influence of the flame and air passing through it. Each turn of the cylinder brings the ore a little further down, and it at last falls into a chamber in a Calcined state. The gases that are formed are conducted into a Flue. This kind of Calciner is what is termed a "delicate feeder" as it requires the ore to be of a certain size, viz $\frac{1}{2}$ inch, and free from dust.

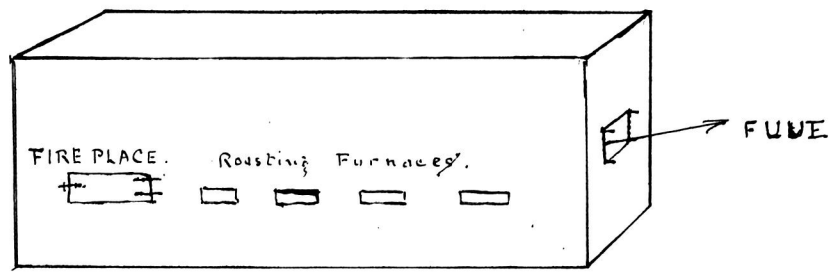
Reverberatory
The ~~Reverberatory~~ Furnace.

This is the oldest kind in use, and will burn anything that can be burnt, It consists of a Chamber of Masonry about six feet high. At one end of the front wall is the fire place, then come the furnaces. The Flue is at the further end. The ore is put into the Calciner through the furnace door near the flue, and it is then pushed towards the fire place by means of long iron spades. The men use rakes to turn over the burning ore in each Calciner.

The crushed Mundic is placed in one or other of these Calciners and roasted. The Arsenic and Sulphur are oxidised and pass into the flues as Arsenious Acid and Sulphurous Anhydride, together with the products of combustion. The residue left is raked out and is called "Wrinkle".

The Flues commence at the Calciners and gradually ascend to the bottom of a tall Chimney: two measure 1400 feet in length, and one 2200 feet. In one Works the Flues are over a mile long and have a capacity of

REVERBETORY FURNACE.



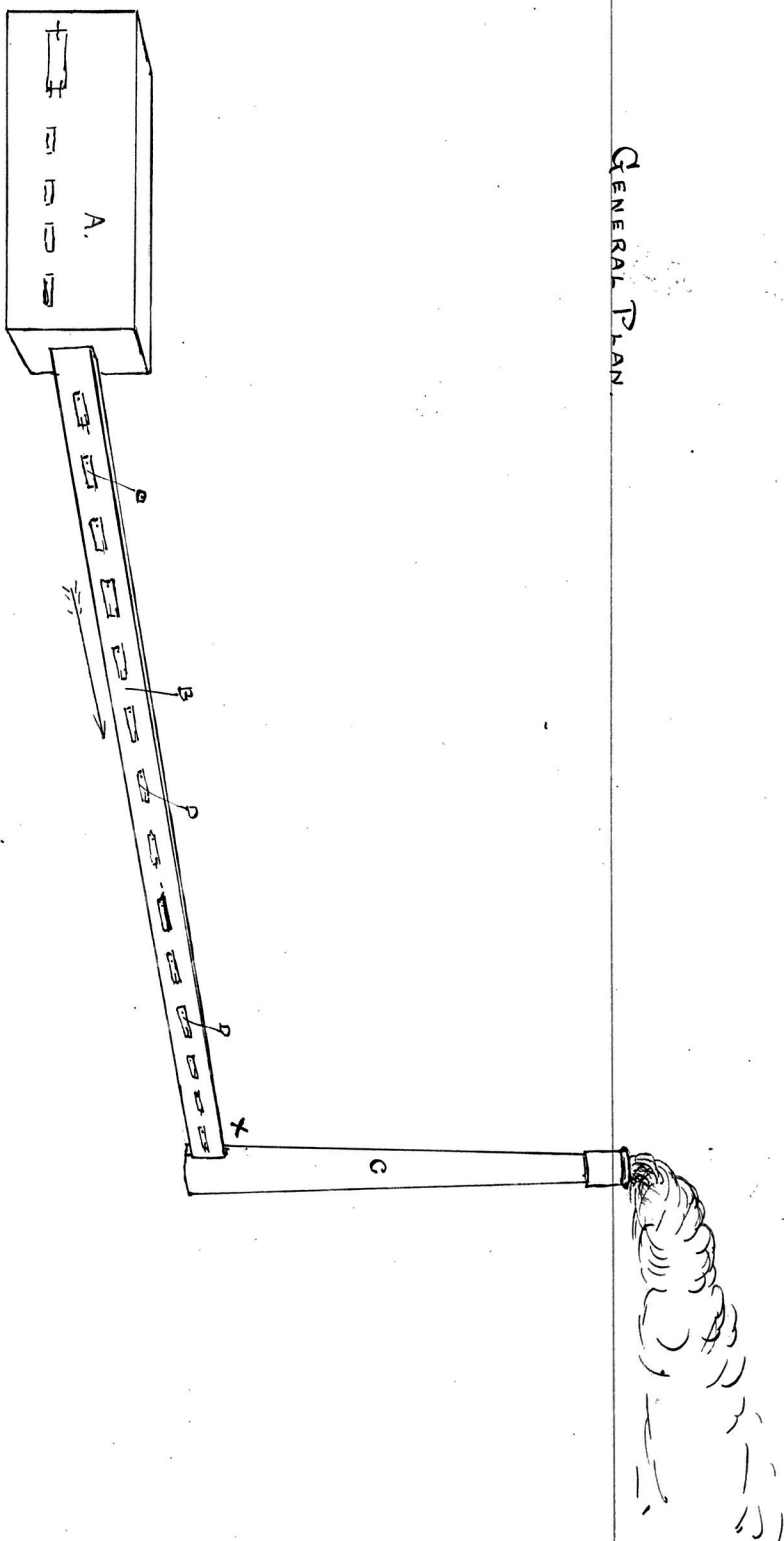
242461 cubic feet. These flues are brick ways, 6 feet square, the roofs of which are covered with sheet iron so as to allow condensation to go on more rapidly.

Within, chambers are constructed in the course of the flues and are provided with iron doors, through which the men can enter and remove the Soot, the name given to the Arsenical deposit. As all the products of combustion pass through the flues, between the furnace and the Chimney, this Arsenical deposit is discoloured by the dust and soot of the fire, and must consequently be resublimed in a refining furnace.

The Arsenious Acid falls to the bottom of the flue all the way up, and by the time the chimney is reached most of it has been condensed. This forms the Arsenic Soot and contains about 96 % of pure Arsenious Acid, with some Carbon &c. The soot near the Calciners is dark, from the admixture of Carbon from the fires, and owing to the greater heat is formed into solid cakes, often like bricks, that nearer the chimney is whiter and more powdery. The Sulphur passes through the flue as Sulphurous Anhydride into the chimney, where it is especially treated in Condensers to prevent its escape into the air.

The, Chimneys, which are tall, are at the end of the flues. They receive the smoke from the furnace fires, as well as the Sulphur, in the form of Sulphurous Anhydride, and any Arsenic that might escape condensation in the flues. Care is taken to purify the smoke from the flues as much as possible, and

GENERAL PLAN.



- A. Calciner.
- B. FLUE.
- C. Chimney.
- D. Doors into Flue.
- X. Position of Condenser.


Free it from Arsenic and SO_2 before it rises up the chimney, otherwise if the wind carried it from the exit down onto the trees or crops it would kill them. Sometimes, when Arsenic has escaped from a chimney and fallen on to the surrounding land, the grass, and leaves of the root crop, have had holes eaten through them; also cases of poisoning have been known to arise in cattle which have eaten grass near a chimney; the symptoms were those of Arsenic poisoning, *as seen* when it is given by the mouth, either in solution or powder. The stomach and bowels showed signs of acute congestion, with ulceration. Tongue red and ulcerated, diarrhoea present. In the lungs was found bronchitis and patches of gangrene, as if the particles of Arsenic had been inhaled and caused destruction of the lung substance in its vicinity. The animals wasted away and many died. The stomachs &c showed the usual signs of Arsenic poisoning, and the test gave Arsenic present. Oxide of Iron did some good as a treatment. Sometimes the Horses eat the Arsenic Soot, when engaged in carting it away, and develop all the symptoms of Arsenic poisoning. It being sweet they like licking it, when the lips, tongue, ~~oesophagus~~, stomach and bowels would be acutely congested and ulcerated, the lips even dropping off. The poor animals would be very ill and die in agony.

In order to prevent the smoke from the chimneys doing harm to vegetation and animals near it, certain precautions are taken to purify it, before it

passes into the air; and since the Alkali &c Act came into force (1893) much improvement has been done in this respect. The purification of the smoke is done in

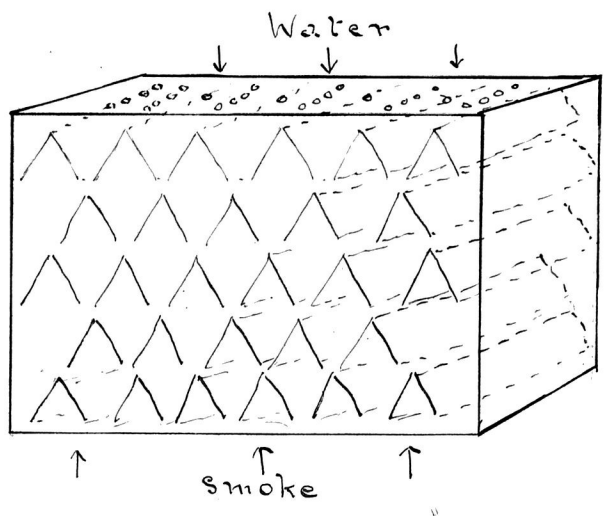
Condensers which are placed in the end of the flues near the chimneys and are of two kinds viz. Wet and Dry.

The Wet Condenser consists of a kind of wash tower, where the Arsenic smoke meets with a shower which washes down some of the solid matter and removes most of the SO_2 . But the power of water to take hold of solid matter such as Arsenic, when in a state of extreme subdivision is small, and its use for this purpose not to be recommended, as besides wasting the Arsenic it has the effect of poisoning the streams and causing destruction to the fish.

At the Carnon Arsenic Works I saw the following kind of Wet Condenser in use. The Condenser consists of a wooden box in the construction of which no metal is used as the flumes would eat it through. On the top of the box is a cover which has holes pierced through it to allow a stream of water to pass into the box. In the box are twelve rows of wooden  shaped pieces placed as shewn in the drawing. The water falls from one to the other and finds an exit at the lower part of the box, it then is allowed to percolate through the soil and finds its way into the river near. This water contains some undissolved Arsenic, some in solution, and some Sulphur.

The Dry Condenser is more effective in collecting

WET CONDENSER.



the Arsenic. It consists of a ten-foot cubical box the upper portion of which is either filled with common broom, furze, brushwood, straw, or steel wire,

the latter being the best as it is more lasting.

This brushwood &c rests on horizontal bars, below which is an empty space through which the smoke enters. The brushwood is shaken by means of a bar of iron passing through holes in the side of the chamber and is thus cleared of the collected Arsenic, which falls into the space below. By means of the dry filter the Arsenic escaping into the chimney is brought below 1/10th of a grain per cubic foot.

The best way to purify the smoke is to pass it first through the dry condenser, which removes most of the finely suspended Arsenic and then through the wet condenser which removes most of the acidity which consists of Sulphur in the form of Sulphurous Anhydride.

All the Arsenical soot is burnt over again in the Refining Furnaces.

When the calcining flues are cool the doors are opened and the men remove the soot which is taken in tram-waggons to a small brick house so that it may not be left lying about and be a source of danger.

When required it is carried in wheel-barrows to the Refining Furnaces to be burnt over again. These are on the same principal as the ~~Reverberatory~~ ^{Reverberatory} Furnaces with the exception that best anthracite coal is used in the fires, so as to cause as little smoke as

possible. Here the soot is purified, and when removed from the flues is perfectly white, the carbon having been removed. It is now ready for the Mill.

The Mill consists of an ordinary stone grist mill. It grinds the crystallised Arsenious Acid from the refining chambers to a very soft powder, the colour of which is as white as the best flour. The Arsenic is now ready to be packed in Barrels which is done on the floor beneath. The Barrels when full weigh from three to four cwt. the weight of each being painted on the end with the number and name of the Works. When the bung is inserted a piece of tin is placed over it to keep it secure and prevent waste. The refiners Waste is called Wrinkle, it is burnt over again in the old ~~reverberatory~~ ^{reverberatory} furnaces. It contains 6 to 9 % of Arsenic and about 20 % of Iron. The ^{final} waste from all the furnaces is taken up to a big heap. It is dark and contains £3 worth of metal in each ton, the metals being Copper, Tin, Gold, Silver, and some Arsenic. At present it would not pay to burn over again.

Having described the processes employed in the manufacture of Arsenic we may now enquire to what uses such a large amount of Arsenic, viz. over 5000 tons a year, is put.

Arsenic is used in the manufacture of Sheep-dips, weed-killers; in glass making (in plate glass where 12 to 20 % of Arsenic is used to eliminate the green colour from the glass) Also in the manufacture of shot and in tempering steel; in making paint, ~~where~~

it is used for fixing Aniline dyes; in colouring papers and printing. The manufacture of Arsenic Acid and Arsenate of Soda is chiefly conducted in the West Riding of Yorkshire and Lancashire for dye and calico printing works, where ^{they are} ~~this~~ largely used for making Paris Green. About 200 tons is sent annually to North America for spraying potatoes when they have the potato disease, and for destroying the larvae of the Colorado Beetle. Some is sent to South America, South Africa and Australia for preserving hides and making Sheep dip. Arsenic soot is used sometimes as a dressing for land and in certain proportions it improves the crop. Near Arsenic Works potatoes grow well and are free from disease.

The process of the manufacture of Arsenic has been fully described so that we can easily distinguish those parts which are injurious to the health of the workers.

After the ore has been raised to the surface of the ground by the miners, the whole process is carried on above ground, in sheds, which are left open to the air as much as possible. The Arsenic Mundic is non-poisonous, it becomes harmful during and after the process of sublimation. The most unhealthy part of the process is working at the Calcining and Refining furnaces. (a) When the men open the doors of the furnaces to rake over the burning mundic there is sometimes an escape of fumes, which is termed smeech, the amount depending on the direction and force of the wind. This smeech consists of Arsenious Acid, either in the

form of vapour or very finely divided powder, and Arseniuretted Hydrogen, & Sulphurous Anhydride.

(b) When the well-burnt ore has been scraped out of the furnaces to the ground below, water is poured on it to cool it quickly, that it may be removed to heaps by itself. The fumes arising from watering this wrinkle are very unhealthy, as they contain Arseniuretted Hydrogen.

(c) Another unhealthy part of the process is cleaning out the flues, especially when the men enter them before sufficient time has been allowed for them to cool. The quicker they are entered the more easily the men can remove the Arsenic, especially when it has got in to a hard mass, as it does near the furnaces and requires to be cut down, but it is more injurious as more Sulphurous Anhydride is present.

(d) Working at the Mill, and packing the Arsenic is injurious owing to the fine dust which, coming in contact with abraded surfaces on the hands, mouth, and eyes causes inflammation and ulceration.

The Precautions taken for lessening the injurious effects are

1. With regard to the works

(a) By seeing the ventilation is good.

(b) Keeping the flues in good repair.

(c) Watering and brushing the floors and walls of the buildings and passages.

By these means the air in the works is kept as free as possible from gases, and particles of finely divided Arsenic.

2. With regard to the men.

(a) to compel them when working at the dangerous parts to wear some form of respirator to cover the mouth and nostrils.

In the Tamar Valley, plugs of cotton-wool are inserted into the nostrils, and an ordinary cambric handkerchief is folded 7 or 8 times and placed over the mouth like a muffler, the corner of which hangs well down over the chin.

In West Cornwall the men "tie up" with a wet sponge, which is placed over the mouth and nostrils, and is kept on by a piece of tape, which passes over the ears. These men prefer this to the handkerchief and wool. The sponge must be kept well clean^{ed} and be worn wet. There are several kinds of respirators manufactured and supplied by Wallach Bros 57 Gracechurch St E.C. but I am told the men prefer the sponge, or wool and handkerchief to more elaborate ones.

usual on Alkali
1900. P. 60. The chief Inspector of the Alkali & Co works Mr. R. F. Carpenter says "From experience in other chemical industries I should deprecate the proposal, were such made, to prescribe any particular form of respirator. No single form is adaptable to all varied conditions. The men know by experience, what form is best to prevent Arsenic sores, and all agree that the simplest forms present the greatest advantages, where Arsenic alone has to be guarded against".

(b) The use of Tower's absorber protects the men from the Acid gases.

(c) The use of spectacles protects the eyes when the

men are cleaning out the flues and also when working at the Mill.

(d) In the Tamar Valley it is common for the men to apply fullers earth to their cheeks, forehead, and neck but this is not the custom in West Cornwall.

(e) Gloves are worn by the men when handling Lump Arsenic, and when working at the Mill. Nail-brushes, soap, water, towels, overall suits are provided.

(f) By the Factory and Workshops Act 1878 to 1895 special rules are framed relating to the duties both of employers and employed. According to these rules the Managers have to provide suitable washing conveniences, respirators and overalls for the men, and the men are bound, under a penalty, to make use of the same, and also not to eat or smoke whilst on the Works.

We now come to the last division of the subject viz. the Diseases to which the Employees are most prone, and in treating this portion of the subject, I shall give

1. The views of the medical Officers of Health of the East Cornwall district.
2. The views of the Managers.
3. The result of my own examination of some of the Workmen.
4. The views formed by myself.

1. The views of the Medical Officers of Health of the East Cornwall District, (Drs. Arlidge and Ballard)

The Tavistock Guardians directed their Medical Officers, Drs. Broderick and Bowhay, to draw up a report on the diseases of employees in Arsenic Works in their Union. This they did, and the report appeared in the Tavistock Gazette March 3rd 1899. The report deals with the Calstock district of the Tavistock Union only, because practically all the employees reside in that parish. Their report deals with the following questions

- (a) To what extent does pauperism prevail in the families of former employees?
- (b) To what special diseases are the employees subject
- (c) How such diseases are produced
- (d) What measures can be recommended with a view of minimising any ill effects resulting from the nature of the employment.

With regard to the first question. "To what extent does pauperism prevail in the families of former employees?" The following table given me by Dr. Bowhay M.O.H. Calstock district Cornwall, is of interest.

Paupers amongst
"All occupations" excluding
Arsenic workers.

Paupers amongst
"Arsenic workers."

| | | |
|---|-----|----|
| Total | 140 | 18 |
| Average age when disabled | 58½ | 40 |
| Those who suffer from respiratory diseases. | 51 | 15 |
| Percentage of respiratory diseases. | 26 | 83 |

From this table it will be seen that there are 18 families in receipt of parochial relief, in which the wage-earner was formerly employed in Arsenic manufacture. The age when disabled is 40 years, as compared with $58\frac{1}{2}$ for the rest of the pauper population.

From the report we see:

- (a) Number of Families in receipt of relief, 18
- (b) Average age when men are disabled, 40 years
- (c) Average duration of employment, $11\frac{1}{2}$ years.
- (d) Number of dependents, 72.
- (e) Total amount of relief per week £4:1:6.
- (f) Average per family 5/-.
- (g) Average duration of relief 4 years 10 months.
- (h) Habits of the 18

- 1. Abstainers 4.
- 2. Moderate 8.
- 3. Intemperate 5.
- 4. Not ascertained 1.

The population of the Parish is 6140. The percentage of Arsenic Paupers to Arsenic Workers is 11.2.

The percentage of non-arsenic paupers to non-arsenic workers is 2.28.

The percentage of the total number of paupers in the parish is 2.57.

From the above we see that the percentage of paupers amongst the Arsenic population (11.2) is greater than that amongst the non-arsenic population (2.28).

Also that the average age when the Arsenic men are disabled is 40 years, as compared with $58\frac{1}{2}$ amongst the non-arsenic.

(b) To what special diseases the employees are subject. On looking into the report we find that the 18 Arsenic paupers suffered or are suffering from the following diseases,

| | | |
|------------------|-----------|---|
| Bronchitis | 12 (66 %) | } Respiratory diseases 15 = 83 per cent. |
| Pneumonia | 2 | |
| Phthisis | 1 | |
| Heart disease | 1 | |
| Mania | 1 | |
| Locomotor Ataxia | 1 | |

From this we see that of the 18 Arsenic workers unable to work on account of ill-health, 83 per cent suffer from respiratory diseases, and of these 66 per cent are due to Bronchitis. During the last three years out of every 100 deaths amongst persons of all ages in this parish (Calstock) 26 have been due to diseases of the respiratory organs, as compared to 83 per cent in Arsenic men.

Dr. Jarvis "It is evident that with such an unusual proportion
of the parish. of one particular disease in the most able bodied
March 3rd portion of the community there must be a definite
99. exciting cause".

(c) How such diseases are produced*.

The report says that intemperance has been alleged to be the principal cause of failure in health among these workmen, but the table given before shews that total abstainers and intemperatenen are almost equal in numbers.

No death in these cases was due to Arsenic poisoning caused by swallowing an over-dose of Arsenic.

*at: Danislovich**at: March**1899.*

With regard to the conditions under which the men work, the Medical Officers say "That they could not help observing the care which the Managers took to do every thing in their power to conduce to the comfort and health of the employé's" Large fires were burning in the rooms used by the men and a good supply of clean water, towels and soap provided. The respirator used was the folded handkerchief and lint, which has been described already. They say that by placing lint over the nostrils no breathing can take place through the nose; while owing to the impermeability to air of a handkerchief folded 3 or 4 times thick no air can pass into the mouth, except such as is drawn under or around the edge of the handkerchief, and which is consequently not filtered at all.

Men working at the flues and who wear this respirator can wipe out of the mouth a black deposit of soot and the expectoration is tinged black.

The Medical Officers Report,

(1) We have the manufacture of a corrosive poison noted for its irritating effect on the mucous membrane.

(2) The air passages of the workmen imperfectly protected.

(3) Consequent diseases and death-rate from respiratory diseases out of all proportion to the general population.

(d) What measures can be recommended with a view of

minimising any ill effects resulting from the nature of the employment?

These Medical Officers consider "That a remedy, to a considerable extent can be found in the wearing of a suitable mask; such as one made of a wire framework fitting closely to the face, reaching above the nostrils and below the mouth and covered with one or more thickness of gauze, so fastened on as to admit of being removed daily".

In "The Diseases of Occupation" by Arlidge, p.p 432-3 I find that Dr. Bowhay says that "the men who work on the surface, under sheds, exhibit no special ailments; and the only workmen who do suffer are the Calciners who are exposed to the sulphurous fumes that escape when the Calcining Furnace doors are opened and (which fumes) cause Bronchitis: and the Millers and Grinders, who get eczema and ulcers of the skin from contact with the Arsenic. Nervous Disorders are no more common, and epidemics are as common among the Arsenic workers as other labourers", "The eczema is commonly present in the folds of the neck and around the nostrils. A scratch on the skin, or a slight abrasion on the foot grows quickly into an ulcer, which can only be healed by the sufferer remaining away from the works for some time.

The Bronchitis supervening on inhalation of Sulphurous Anhydride escaping from the Calcining furnace is acute: the patient complains of a burning feeling in the throat and chest, and after some days, when the

Dr. Jarvis's book

Dr. Marsh

1899.

Names of
occupations by
Liddle, p.p. 432-3.

expectoration becomes copious, he finds relief, and the attack runs a more normal course".

Dr. J. T. Arlidge adds "That the severity of the chest attacks as above represented suggests the probability that some small proportion of Arsenical vapour, or of Arseniuretted Hydrogen, is mingled with the Sulphurous fumes; for neither my own (Dr. Arlidge's) observation, nor any enquiry made of others, respecting the labourers who roast the Sulphur Ores in Sulphuric Acid Works, and get frequent inhalations of Sulphurous Anhydride, indicate that they experience Bronchitis of like severity".

Dr. Powhay tells me that in his experience the difference between the lung symptoms of Arsenic men and miners - that is men who work underground - is this,

1. Arsenic men expectorate more like that in acute bronchitis. The miner to begin with has slight Bronchitis, with coexisting emphysema.

2. Arsenic emphysema is secondary to Bronchitis, in miners it is coëxistant with it.

3. Arsenic men become earlier disabled and die earlier. The miners are about 20 years later in the symptoms and life only slightly shortened. Average age of death of miners being about 65.

4. The miners get Fibroid Phthisis. Dr. Ballard (Local Government Board Report on Effluvia Nuisances P. 257) says "On the question of health to the workmen in the Calcining or burning houses for Arsenic ores, the fumes produce gastric disturbances in some cases, and Bronchial & laryngeal irritation in other cases and

al Government
rel Report, on
Curium
Nuisances. P. 257.

(this appears more common) an eruption about the genitals and on exposed parts of the body, especially at the flexures, causing great annoyance".

2. The Views of the Managers.

Mr. Bawden, the Manager of the largest Mines, (one of) which (D.G.C.) employing 450 miners, and 85 Arsenic men, in an interview told me "that there is a sick Club in connection with the largest mine, viz Devon Great Consols, and he has received for the last year 5 certificates for bronchitis in men working outside the works, as compared with 2 amongst Arsenic men. (This gives 1 in 90 for non-arsenic men, as compared with ^{1 in} 42.5 in Arsenic men). He denies that Bronchitis is more frequent with Arsenic workers than with other miners. He thinks the Bronchitis seen amongst them is due to the men often taking colds by sweating in their work before the furnaces, and then standing in a cold draught. The great thing is cleanliness and sobriety, given this, the men can work in the Arsenic Works as long as anywhere."

The precautions he suggests are,
Good ventilation, careful washing, the use when handling the Arsenic much of leather gloves.
No special dress, as leather, is needful. but the men should change their ordinary clothes for working ones. Some flannel to be provided for the men to wipe themselves down with when they leave the hot part. The use of the present respirator, viz cotton wool

and handkerchief. Air can hardly get under, as stated, and it is far better than a wire respirator.

Mr Trythall Manager of the Carnon Arsenic Works west Cornwall, in a personal interview said "Before improvements were made in these works the men suffered very much from nervous complaints.

In Manchester, where they make soap, and use Arsenic, the men shake and come out in blotches.

The chief things to attend to are

1. Sufficient draught and length of condensing chambers to prevent smeech.
2. Flues kept in good repair.
3. Temperance.
4. Cleanliness. Use of sponges, nailbrushes, soap and towels, and keeping the roadways and walls of the works watered to prevent dust.
5. Use of the sponge respirator".

Mr. Davey, Manager of the Cornwall Company's works in an interview said, "There ~~are~~ are 20 men employed in these works, 7 employed in Arsenic works proper. These 7 enjoy good health.

The Arsenic men do not complain; sometimes they get a little indigestion, and the older ones get a little short in the breath, but they do not suffer much from cough, or expectoration. Have seen one or two shake.

The men come to the works regularly and are clean and temperate, careful in using the sponge respirator. The walls and Yards are watered to prevent dust rising. After charging the furnaces they wash, and also on

leaving work and gargle their mouths. No smoking is allowed on the premises. The sponge respirators, soap, water, towels, nailbrushes, and overalls are provided. The sponge respirators being renewed once in 12 months. Spitting blood is unknown. Have tried sveral kinds of respirators, and believe the sponge best, it must be used wet and be kept clean.

3. The Result of my own examination of some of the Workmen.

In my district there are no Arsenic workers, but through the kindness of Dr. Bowhay I have been allowed to examine some of his Arsenic patients.

Daniel Wickett, age 49.

Lived formerly about 20 miles from Arsenic works, and was a farm labourer. He comes of a healthy family, having no hereditary tendencies, and is temperate in habits. He lives at Latchley Vill~~l~~age, which consists of a few houses on the Cornish bank of the river Tamar. His Cottage is small but fairly clean. He works at Devon Great Consols Mine, and has some little distance to walk each day. He has worked at this mine for 19 years, where he has done all kinds of work connected with the manufacture of Arsenic, but has never worked underground.

He has been failing in health for 18 years, and during the last 5 years has not been engaged in the manufacture of Arsenic, but has been doing job-work on the mine, as breaking stones, now (Oct:26,1900) is totally incapacitated from work.

The illness began as a cough, which is worse at night and early morning. Has a good deal of expectoration, which is like dough, darker in winter than in summer. The breath is short, the effort of walking or dressing being difficult on that account. The appetite is poor, and he often vomits, If he eats supper, he gets pains in the stomach, but not at other meals. No diarrhoea. Eyes often red and watery. No nervous symptoms. Complexion pale and unhealthy, hair dark. Height medium. Of rather stout build, temperature normal. Examination of his chest shews the breathing difficult. Chest expanded and further expansion is done with marked muscular effort. The percussion note in front is ^{hy}perresonant, behind resonant. Auscultation, shews the act of inspiration prolonged as compared with expiration. Crepitation and fine bronchial râles, the latter especially over the bases. No valvular disease of the heart but the right side is enlarged, and the beat in the epigastric region increased. Liver slightly enlarged.

Diagnosis.

Chronic Bronchitis, which at times gets acute.

Emphysema, with commencing Dilatation of the right side of the heart &c.

Prognosis.

Bad. The Emphysema will increase. Breath gets shorter, and the heart symptoms seen in such cases will increase.

A son aged 23 is an Arsenic worker, being formerly a farm labourer. He is beginning to suffer from

the bases. Heart free from disease.

Bowels regular as a rule, but may get diarrhoea.

Nervous system.

Soon after being obliged to give up work, on account of Bronchitis and weakness he noticed certain nerve troubles. The first thing was pain, which was more or less all over, but worse in the legs and arms, at times it was of a crushing kind, The pain was more acute on the right side. Then came a shaking or twitching of the feet and hands, producing a sensation of pulling the toes and fingers inwards. Paralysis of the legs and arms was soon seen, with atrophy of the extensor muscles, causing him to walk lame and with difficulty, that on the right side being more marked, he being unable to lift the right foot and in walking drags the toes. There is in-coordination of movement in the legs but the ground feels natural to both feet and deep reflexes are present.

Henry Axford, age 36. Gunnislake.

Height 5 ft, 7 ins. Weight 109 lbs at Xmas. He began to work at Devon Great Consols when 16, for two years he worked on the floors at the mundic, before it was calcined. After this he was engaged in the manufacture of Arsenic, working at all the processes, except the packing. For the first 4 or 5 years he did not lose much time.

The illness commenced with a cough and shortness of breath, with thick yellowish expectoration which occasionally was tinged with blood.

The cough is worse in the morning after getting out of bed and also in the evening when first in bed, not much through the rest of the night.

Some white scars are seen on the exposed parts of the skin, where the particles of Arsenic have fallen.

Tongue is not much coated. Taste, when at work, was like having some salt-petre in the mouth. Sometimes there was a rash on the lips, and sores in the mouth. He suffered at times from sickness and does so still, with pains in the stomach. He used to get "red Arsenic" rash about the folds of the skin of the face, neck and privates. Lungs. Respiration 20. Breathing difficult, at times so bad as to feel as if there was a towel tied in front of the mouth.

Percussion. Is increased all over.

Auscultation. Breathing sounds harsh. Crepitations; marked in front. Bronchial râles, both on inspiration and expiration especially behind, at the lower part of

the lungs. Vocal resonance is not increased.

Heart. The sounds are normal, but the organ is slightly enlarged. Pulse 80, regular but weak.

When seen some months later (Oct:26: 1900) I found him worse. The cough was very bad, and expectoration very copious. He was loosing flesh, his weight being 105 lbs whereas in good heath it was 139.

Gets vomiting two or three times a day, but does not suffer from indigestion. Appetite Good and does not often get diarrhoea.

Pulse 72, regular but feeble.

He now cannot walk far without getting very short in the breath, expectorating a good deal, and getting blue about the lips, hands &c.

Chest. Is thin, and breathing very difficult.

On ordinary inspiration the upper part is drawn up, and the lower in.

Epigastric pulsation, visably marked.

Measurements.

| Above nipple | Expiration | Deep inspiration |
|--------------|-----------------|------------------|
| Left | $16\frac{1}{4}$ | $16\frac{1}{2}$ |
| Right | $16\frac{1}{2}$ | $16\frac{5}{8}$ |
| Below nipple | | |
| Left | $15\frac{3}{4}$ | $16\frac{1}{4}$ |
| Right | $15\frac{3}{4}$ | $16\frac{1}{4}$ |

Auscultation. In front breathing harsh.

At the Apex Crepitations, with sibilant râles.

At the lower part bronchial râles.

Behind. At the top vesicular breathing, with

crepitations with slight bronchial râles.

At the bases breath sounds feeble, and marked bronchial râles.

No nerve symptoms at present of an abnormal kind.

I sent some of the sputum to the Chemical Research Association, 1 Southwarl St, London Bridge, S.E. and received the following Report.

"The sputum marked (A) received here on 18-7-99 has been duly examined, and I have been instructed to forward the following report thereon. No Tubercle Bacilli, or lung tissue, could be found in the sputum. It has been tested for Arsenic with completely negative results." Signed, C.H.Wells.

Kidneys and Urine, nothing abnormal found in them.

Diagnosis.

He is suffering from chronic bronchitis. Emphysema. Dilatation of the right side of the heart. Gastritis, and Erithe~~ma~~ between the folds of the skin.

Prognosis.

Very bad. Health gradually failing.

Samuel Buller, aged 34.

Height 6ft, 1½ ins. Weight 138 lbs.

Has been an Arsenic worker for 14 years, and has worked at all the processes, but never under ground. For 12 years he worked fairly well but about six years ago the cough came on, which, he says, is a very common complaint among the men. Three years ago had acute bronchitis. Has now been off work 4 years, on account of ill health. The eyes do not burn now, as they did when he

was at work, but they still get ^efiry and he has some conjunctivitis.

Taste in the mouth, when at work, was sweetish. Tongue grey coated.

When working the skin used to get red over the head, nose, mouth, neck, between folds of the skin, and about the privates. The skin in many parts is dark coloured especially over the chest.

He does not vomit, but gets diarrhoea, and often a burning pain in the stomach, which does not seem to have any connection with meals.

He gets troubled with a cough and expectorates a yellow mattery looking stuff, which comes up easier at times than at others, and is occasionally tinged with blood.

In July 1900 he spat a good deal of blood.

Chest is thin. Breathing difficult. Marked cardiac pulsation in the Tricuspid area.

Lungs. In front. Right Apex. Inspiration rough and prolonged. Crepitations. Expiration feeble.

Lower part, in front, breath sounds more feeble, no râles,

Left Apex, in front, the same as right.

Posteriorly. Breath sounds feeble with bronchial râles.

Heart. No valvular disease, but tricuspid sound is impure. Pulse 84. Regular but feeble. No abnormal nerve symptoms.

Kidneys healthy.

Family history. Father, at first was a farm labourer, then worked in Arsenic works 18 years. Died, age 51.

Of breath complaint.

Mother, living 55. "Weak on nerves"

Brothers. Three living. Tom, 30, worked ten years at the Arsenic Works. Breathing got bad, so went to work at Devonport at the dock works, but had to leave on account of ill health.

Fred, 25, Arsenic worker 2 years. now working at the Devonport Dock works, but is not strong in his chest.

Jack, 23. Arsenic worker 2 years. Now working at Devonport Docks and in good health.

One brother dead, of inflammation of the bowels, when 11 years old.

Sisters. 4. One dead, due to Phthisis.

Other 3 well.

No history of Phthisis either on father's or mother's side.

Diagnosis.

Bronchitis. Emphysema. Dilated right heart. Gastric trouble.

Prognosis. Bad.

Benj Phaer. Age 45.

Worked 10 years at the Devon Great Consols Arsenic Works, doing all kinds of the process except the Mill. Was a carpenter and a farm labourer at first and as such enjoyed good health. Has been ill at home 8 years. The illness began with a cold. Cough which was not very severe. Neither was there much expectoration.

He thought he hurt his back in his work, which caused

a pain like lumbago, the pain being worse on the left side . After this he felt weak all over, especially on the left side. Now he cannot bear his weight on the left leg and cannot lift it so well as the right.

No sickness or diarrhoea.

Breathing only a little short and laboured.

Lungs. There are no very marked symptoms, but when he catches a cold then he gets some bronchitis.

No Emphysema present.

Sound. No valvular lesion or enlargement.

Nervous system.

At first he felt a pain in the back which he thought was lumbago, this was followed by pain in the legs, especially in the left. Soon they became weak and it was with difficulty that he could lift the left foot. The arms became painful and weak, but not to such a marked extent as the legs.

The Patellar reflexes are present and the ground feels natural. No change noticed in the trunk muscles.

Symptoms observed in the Arsenic Workers.

The men are largely taken from the Farm labouring Class, about which statistics make it quite clear that those engaged in it (i.e. Agriculture) head the scale in life value. They live for the most part a little distance from their work, in the country, which is not thickly populated. The houses are those of the ordinary labourers, with plenty of air space around.

It has been already shewn that the men are rather inclined to drink. Drs. Bowhay and Broderick's Report gives of the 18 totally disabled men in receipt of

| | | |
|-------------|-------------|---|
| Parish pay- | Abstainers | 4 |
| | Moderate | 8 |
| | Intemperate | 5 |
| | Not defined | 1 |

Sam Buller, a worker, says that as a body of men the Arsenic workers are drinkers. The process, he says, creates thirst.

Their wages are fairly good, being from £2 to £2:10:0 a fortnight; in the Tamar valley the men are paid by the amount of work they do: in the West of Cornwall, so much a day. The former method may possibly have a tendency to make the men careless so as to get over more work in a short time. With the wages they get they ought to be able to provide themselves with plenty of food, especially where house rent and living are not expensive.

There are three cores or periods of work.

Night 9 p.m. to 7 a.m.

Day 7 a.m. to 2 p.m.

2 p.m. to 9 p.m.

If a man works in the night core this week he would work fore noon core next week and afternoon core the week after.

Soon after the men become Arsenic workers they say they increase in weight, but when the cough begins they lose weight.

This increase in weight may be due to the fact that Arsenic in medicinal doses acts as a stimulant to the trophic nervous apparatus.

The face gets puffy, eyes red and watery, running nose. The gums get sore and pimply, like a white rash, with white heads. The teeth sometimes get loose. The tongue is generally white, with a silvery fur. Taste sweetish, appetite generally good, which I have noticed to be the case even in bad cases.

Thirst is common, which may be partly due to the sweetish taste of the Arsenic, and partly to the heat of the furnaces, causing so much sweating.

A burning feeling is often felt in the oesophagus and stomach, and eating does not increase the pain.

Vomiting is frequent, which does not seem to be brought on by food, but more often helped by the act of coughing. Diarrhoea is very frequent. The act of digestion does not seem to be interfered with, which may be explained by the fact that Arsenious Acid does not affect any of the structureless ferments, as of the Gastric juice, Pancreas &c.

The men look pale although working above ground and more or less in the open air, this is especially noticed in those cases in which the breathing is difficult.

Chronic Arsenic poisoning causes Anaemia, due to a disease in both corpuscles and haemoglobin.

Heart disease is not common as a primary disease.

The work is not hard, and does not require much straining. Secondary to Emphysema we find dilatation, especially of the right side, with marked epigastric pulsation, and venous engorgement.

The pulse in bad cases is weak, and of low tension, and heart feeble. Running nose, husky voice.

One of the most constant and earliest symptoms is a cough, few men escaping from it. Bronchitis is common, which at first is acute, and may pass off, to return again, soon to become chronic, then we get accompanying Emphysema, which steadily increases.

There ^{are} to be seen sometimes some Bronchiectatic cavities but Phthisis is rare, Pneumonia (croupous) is more common than phthisis, and the same with pleurisy, both of which are much less common than bronchitis.

Old scars are seen, where the particles of Arsenic have come in contact with some abraded surface.

A pigmentation of the skin is very frequent, the colour varying from a dirty unwashed appearance to a decided brown hue. It is also more marked in some parts than in others, such as the neck chest, axillæ and thighs.

A red rash is common below the eyes, by the side of

the

the nose and in those parts where the perspiration is most plentiful, as the neck, axillae, groins &c. This is accompanied by a good deal of itching.

Urticaria, Herpes Zoster, Pemphigus, are not more than in the general population, neither do the men lose their hair more than others. Urinary System. I have not found urinary diseases more prevalent among the Arsenic men, more than among others in whom it is customary to take a like amount of Alcohol. The urine when tested, has generally been found normal. Two specimens of urine I examined for the presence of Arsenic with negative results (July 1899). The amount examined might have been too small to give a positive result, or the men examined may have been off work too long. It is eliminated by the urine. After acute poisoning it is to be found for a month or 6 weeks, but after chronic poisoning it may be detected for 6 or 9 months, after the entrance of Arsenic into the System has ceased.

Reproductive System. This does not seem to be injured, as many of the men have long families. The Arsenic causes eczema of the privates as before mentioned.

Nervous System. Amongst the workers in former years "shaking" or "trembling" were frequent, shewing evidently symptoms of commencing neuritis present.

Latterly nerve symptoms are rarely seen. In two workers (Wm Lose and Benj Phaer) I found marked nerve symptoms as described by writers on arsenical poisoning viz: Pain at the extremities; weakness with paralysis of the extensor muscles, causing dropped-ankle, and

atrophy of muscles, shewing that in these

cases periperal neuritis was present.

List of Symptoms seen in Arsenic workers.

Face puffy.

Conjunctivitis.

Gums sore and pimply.

Teeth lose.

Tongue white and silvery.

Taste sweetish.

Appetite, (generally) good.

Thirst.

Burning in oesophagus and stomach.

Vomiting.

Diarrhoea.

Dilatation of right side of heart.

Pulse weak and of low tension.

Running of nose.

Huskey voice.

Cough, (early symptom.)

Bronchitis, (very marked).

Emphysema.

Scars on skin.

Pigmentation of skin.

Eczema-Arsenicalis.

Herpes Zoster.

Keratosis of hands and feet.

Blisters like pemphigus.

Erythromelalgia.

Loss of power of hands and feet.

Paralysis of Trunk muscles.

Ataxic gait.

Knee jerk, at first increased, then absent.

Tenderness of muscles.

The following symptoms are common to Arsenic workers,
medicinal chronic arsenic poisoning cases, and Arsenic
poisoning from Beer.

Conjunctivitis.

Tongue white and silvery.

Vomiting.

Diarrhoea.

Pulse weak and of low tension.

Running of nose.

Huskey voice.

Cough.

Bronchitis.

Pigmentation of skin.

Eczema-arsenicalis.

The following differences are noticed in the symptoms
of the Arsenic men, as compared with medicinal and
beer cases.

Appetite. Generally good in Arsenic workers.

In medicinal cases good at first then
poor. In beer cases poor.

Cough,

Early symptom in Arsenic workers. Slight
in medicinal and beer cases.

Bronchitis.

Well marked in the workers. Moderate in
medicinal and beer cases.

Emphysema, in workers, not seen in other classes.

Dilatation of right side of heart, frequent in workers, not seen in other classes.

Nerve symptoms. Less marked in the workers, than in the other two classes.

With such symptoms seen frequently in the Arsenic workers one cannot but come to the conclusion that Arsenic gets into the system of these men in some form and some how. All soluble Arsenical compounds when once absorbed into the body, ultimately become identical in composition, hence the exact chemical composition in which the Arsenic enters the system is not of great importance.

In whatever form the Arsenic enters the system the ultimate physiological action is the same, although the incidental symptoms may be different. Thus, the Arsenites act on the alkaline mucous membrane of the intestines more powerfully than the Arsenates. Also variations in the action of Arsenic may arise from the degree of coarseness or fineness of the subdivision of the particles of the poison: e.g. the symptoms due to Arseniuretted Hydrogen are apt to develop much more rapidly than those arising from Arsenious Acid.

The points in which the symptoms in the Arsenic workers differ from the others are, that the Arsenic workers often have their gums sore and pimply, teeth

loose, taste sweetish and suffer from thirst, caused I think by the Arsenic getting into the mouth in a finely divided state and possibly in the form of vapour, as proved by the chemical examination of the cloth with which one of the workers wiped out his mouth for me, and which was found to contain Arsenic. In these men dilatation of the right side of the heart is seen, caused by the bronchitis and emphysema present. The Cough is more frequent, and the bronchitis a much more marked and severe symptom. This is due in my opinion, to the admixture with the Arsenic of Arseniuretted Hydrogen and Sulphurous Anhydride, which act as powerful irritants on the respiratory, mucous membrane, and intensify the action of the Arsenic on it; also because the Arsenic, either as fine powder or vapour, is taken into the system chiefly through the respiratory tract, whilst given as a medicine, or taken accidentally in beer &c it is taken into the stomach. It is owing to this persistent bronchitis that emphysema soon sets in. I do not think that the bronchitis is due to working in heated parts, as before the furnaces, and then going into the open air to cool, because I found bronchitis rare amongst the stokers on board a Cape Liner, on which I had nine months experience, and whose work is subject to great extremes of temperature. And it is also rare amongst workers in Gas works. Scars of the skin are seen only in ^{Arsenic} workers, and caused by the solid particles falling on abraded parts.

The nerve symptoms in these men are not nearly so frequently met with as in chronic Arsenic poisoning cases, or in the beer drinkers.

THE CONCLUSIONS I draw from studying this subject,
are these.

That the men employed in the manufacture of Arsenic are generally healthy when they first begin the work, that after a few years many shew signs of commencing ill health and if the occupation is persevered in become quite unfit for work at a comparatively early age; that this is not caused by alcoholism although it may be assisted by it. That it is caused by the nature of the work, the injurious factors of which being,

I. Arsenious Acid. This is in the form of vapour only at a temperature of 380° . So, if such vapour escapes from the Calciners, in the smeech, it must be just as it emerges from the furnace, before it has had time to become solid.

In the form of fine dust it is present wherever there is Arsenical Soot or refined Arsenic. It is true it has a high sp:gr: but wind can raise clouds or even small stones, hence one can understand how in the exposed and open buildings Arsenic in the fine powder can be more or less present in the air.

In the smeech, I believe, there is some present in a finely powdered form. In the flues, where the contents are being cleaned out some must rise into the air as fine dust. The air of the Mill and packing room

must contain some also. So also the passages.

II. Arseniuretted Hydrogen, which is met with in the smeech, and also when the wrinkle is watered.

III. Sulphurous Anhydride, which is present in the smeech, and in the fumes which arise when the wrinkle is watered, but especially met with in the condensing flues.

The injurious products in the manufacture of Arsenious ^{Acid} ~~Anhydride~~ are,

I. The Arsenious Acid,

II. The Arseniuretted Hydrogen.

III. Sulphurous Anhydride.

The Arsenious Acid enters the system slightly through the abraided surfaces of the skin. Some gets into the mouth, but as it is very sparingly soluble it does not enter into the system very quickly or to a large extent by this means.

As vapour or fine powder it is inhaled into the lungs, and acts as a powerful irritant upon the bronchial mucous membrane and through it is absorbed into the system.

The Arseniuretted Hydrogen is fortunately not present in large amounts; it is rapid and powerful in its action and being inhaled into the lungs causes irritation of the bronchial passages, with ultimately the general effects of Arsenic poisoning, as the Arsenic is absorbed through the lungs into the blood.

The Sulphurous Anhydride is present in varying quantities, depending on the amount of sulphur which is

present in the given specimen of mundic. It is inhaled into the lungs and causes dryness of the throat, huskiness, and spasmodic cough, and after prolonged exposure bronchitis.

I have not been able to make a post-mortem on an Arsenic worker. This is most difficult to do in this neighbourhood owing to the objection the relations have for its being done.

Since the Arsenic Works have been under the control of the inspectors of the Alkali &c works much improvement has been noticed in the health of the men.

The Managers are doing much good by providing suitable means for washing, overalls, respirators of a sort preferred by the men, and seeing that the works are kept in good repair, with the latest improvements, especially with regard to the length of the flues and suitable condensers, and attention paid to their being kept clean. The men, on their part, might greatly help themselves by being a little less careless often, and in making more use of the things supplied them for their benefit by their masters and in some cases being more temperate.

Wm F. Thompson.

M B C M

Penguito

Launceston

Cornwall

March. 1907.